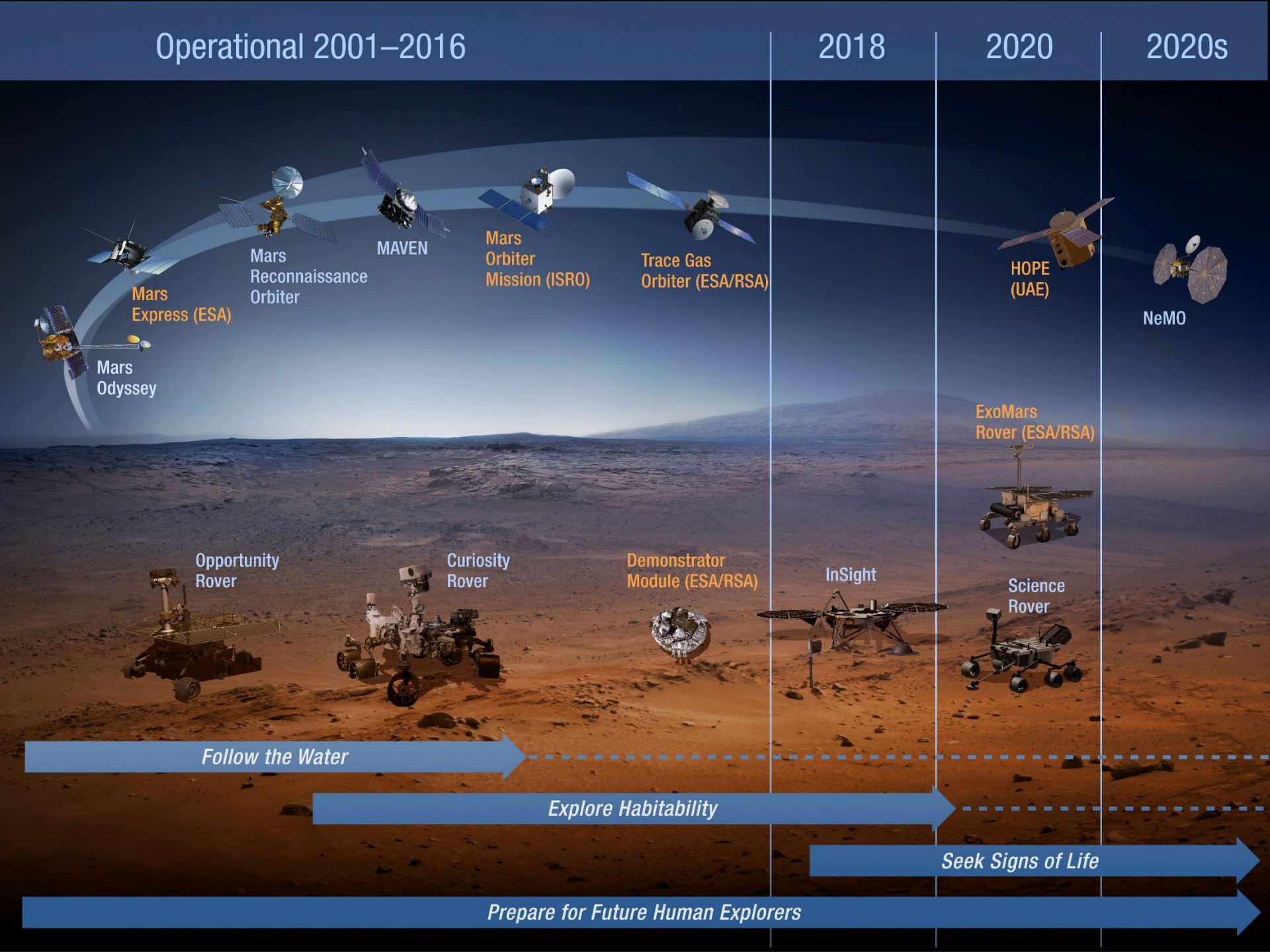
Mars Exploration Program (MEP) Update

Planetary Protection Subcommittee Meeting

June 1, 2016

Michael Meyer
Lead Scientist, MEP


Operational 2001–2016
2018
2020
2020s
Mars Express (ESA)
Mars Odyssey
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA/RSA)
HOPE (UAE)
NeMO
ExoMars Rover (ESA/RSA)
Opportunity Rover
Curiosity Rover
Demonstrator Module (ESA/RSA)
InSight
Science Rover
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

The state-of-the-MEP today

Our operational assets remain healthy and productive – Senior Review for Extended missions completed last week:

- ✓ MAVEN has successfully completed its prime science mission and is now continuing investigations in an extended mission
- ✓ Odyssey, our oldest Mars asset, continues to be healthy and contribute thermal imagery and data relay services
- ✓ Opportunity continues to provide important ground truth data, recently scaling 30 deg slopes of Knudsen Ridge atop the southern flank of Marathon Valley, to investigate red zones
- ✓ MRO continues to provide invaluable reconnaissance imaging and mineralogical mapping, supporting science investigations, rover operations, and exploring potential human landing sites
- ✓ Curiosity has completed two Mars years on the surface exploring Gale Crater, generating important insights into martian environment
- ✓ Mars Express continues operating our collaborative deep radar sounder (MARSIS) and the Analyzer of Space Plasma & Energetic Atoms (APSERA)

The state-of-the-MEP today

M2020 development on-track and proceeding well:

- ✓ Project Confirmation Review (KDP-C) held on April 27 with open actions
- ✓ Heritage hardware fabrication underway; some delivered
- ✓ Sampling system development labs up and running

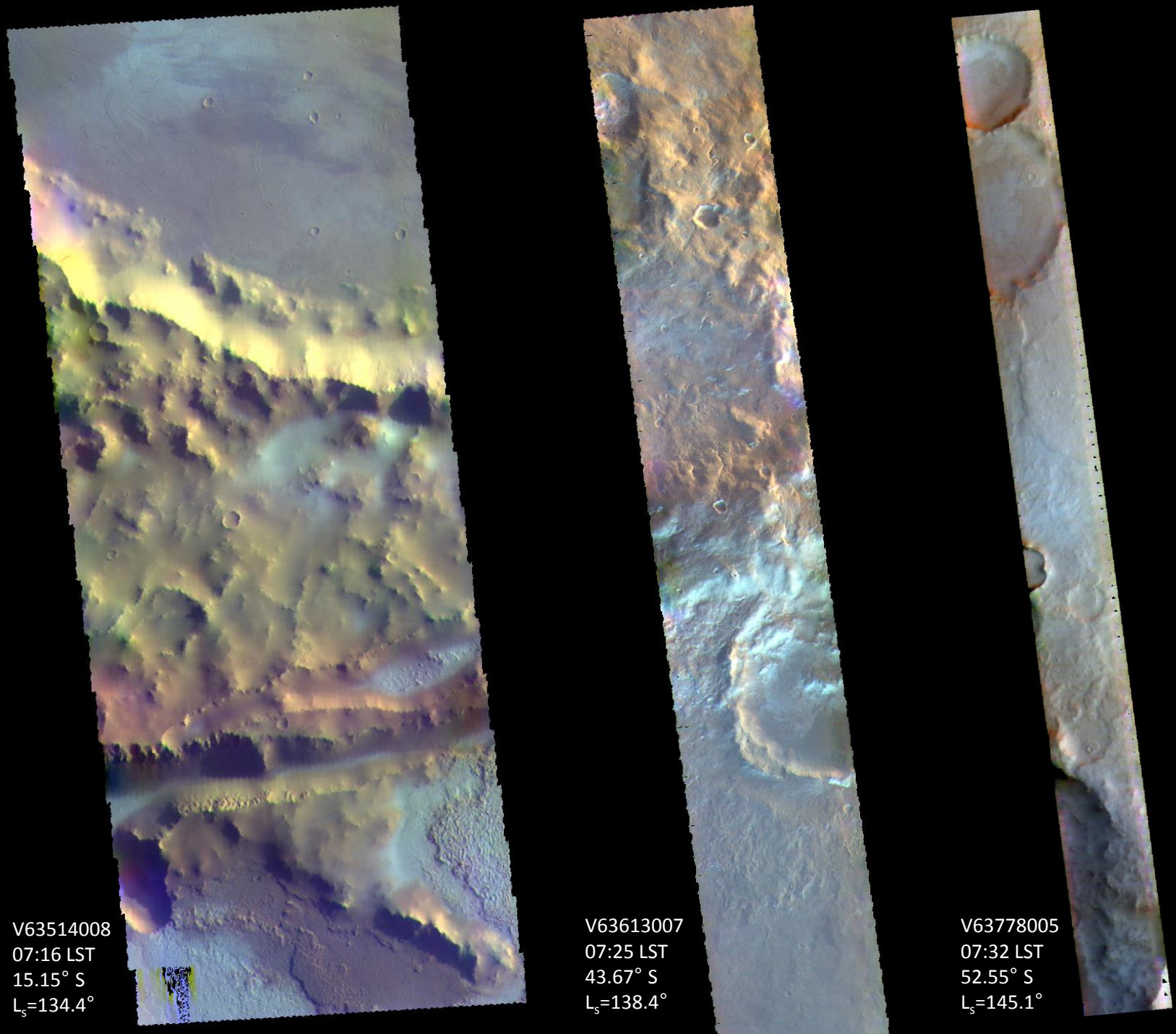
We are meeting our foreign commitments:

- ✓ Our two Electra payloads on the Trace Gas Orbiter are on the way to Mars
- ✓ MOMA in development, ExoMars Lander postponed to 2020

Financially, the program is doing well:

- ✓ This fiscal year all our planned activities are funded
- ✓ President's FY17 budget was released, supporting our development, operational, and future mission activities

Overall, the state-of-the-MEP is good



V63514008
07:16 LST
15.15° S
L_s=134.4°

V63613007
07:25 LST
43.67° S
L_s=138.4°

V63778005
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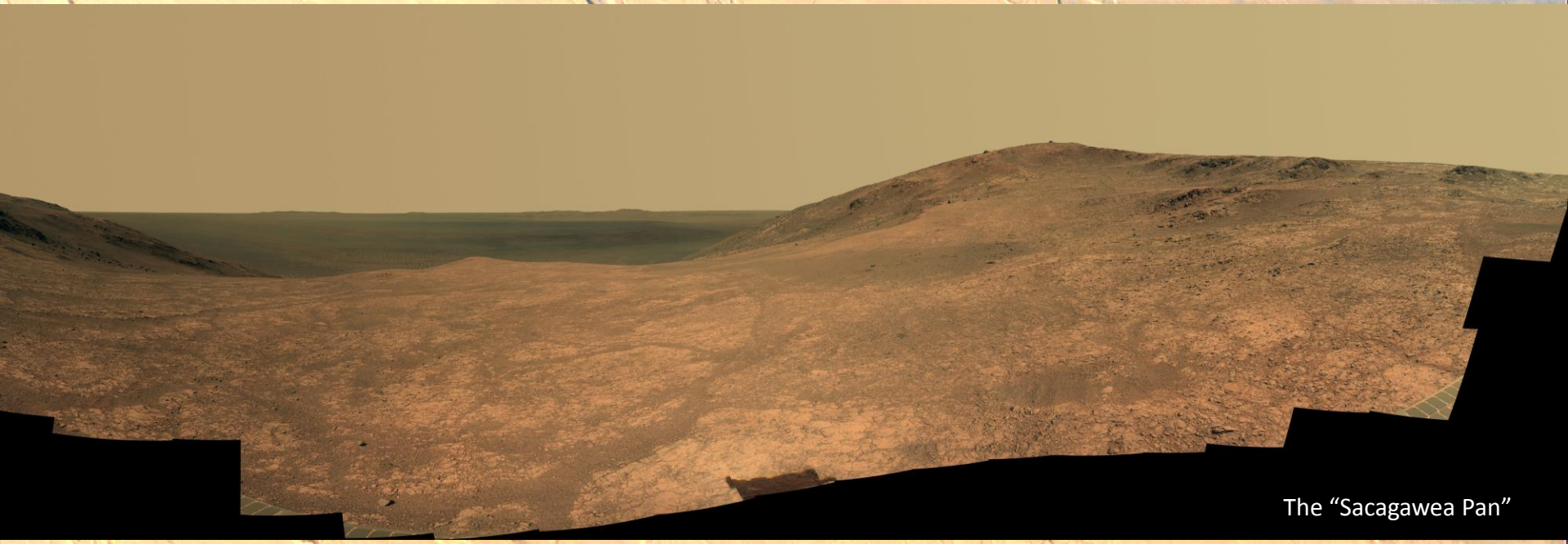
52.55° S
L_s=145.1°

Opportunity's View Today



The "Sacagawea Pan"

Recent Science Highlights

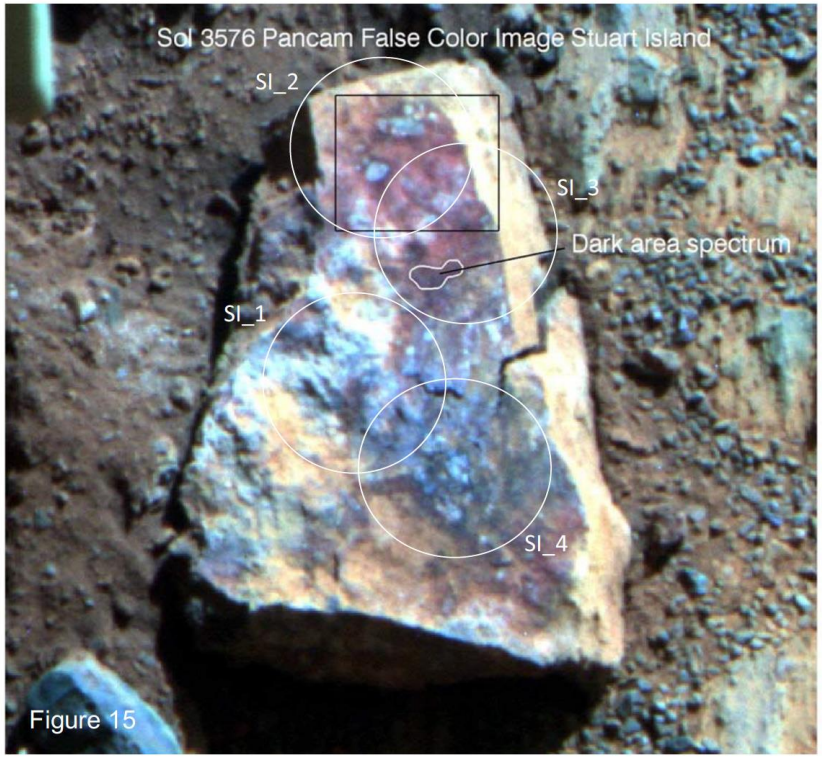
High Concentrations of Manganese and Sulfur in Deposits on Murray Ridge, Endeavour Crater, Mars

Raymond E. Arvidson[1], Steven W. Squyres[2], Richard V. Morris[3], Andrew H. Knoll[4], Ralf Gellert[5], Benton C. Clark[6], Jeffrey G. Catalano[1], Brad L. Jolliff[1], Scott M. McLennan[7], Kenneth E. Herkenhoff[8], Scott VanBommel[5], David W. Mittlefehldt[3], John P. Grotzinger[9], Edward A. Guinness[1], Jeffrey R. Johnson[10], James F. Bell III[11], William H. Farrand[6], Nathan Stein[1], Valerie K. Fox[1], Margaret A. G. Hinkle[1], Wendy M. Calvin[12] and Paulo A. de Souza Jr.[13]

Surfaces exposed by rover wheel action have the highest concentrations of Manganese (Mn) and Sulfur (S) measured by Opportunity.

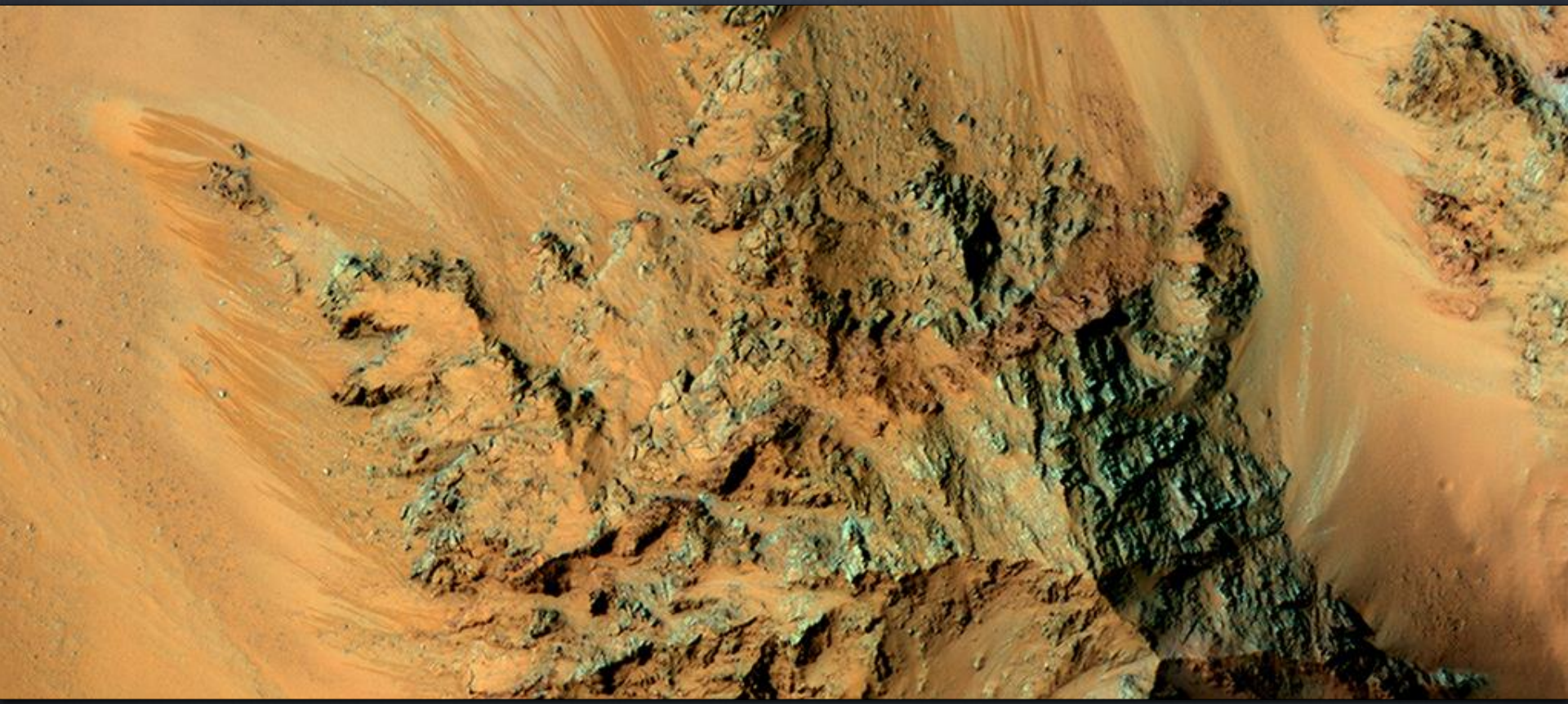
Pancam spectral properties are consistent with Mn oxides.

We infer subsurface precipitation of sulfate-dominated coatings, followed by partial dissolution and reaction with one or more strong oxidants to produce Mn oxides intermixed with sulfate-rich salts.



After 10+ years of operation, the 6 MRO science instruments retain their key capabilities for science observations.

- Highest resolution orbital imaging (HiRISE:~25-30 cm/pixel; CTX: 6 m/pixel) and imaging spectroscopy (CRISM: ~7*-20 m/pixel).
  - * *Intrinsic resolution is 18-20 m/pixel; smaller features resolved by over-sampling.*
  - Reveals morphologic and compositional character of the surface
    - Change detection and many new phenomena (e.g., RSL) observable only at the highest resolutions. Change detection aided by long data record.
    - Complex planet, evolving through different water-related environments; implications for habitability just now emerging.
- Highest resolution subsurface radar (SHARAD: 15 m free space)
  - Enough CO_2 ice buried in the south polar cap to double atmosphere
  - Internal stratigraphy of the polar caps and correlation with obliquity cycles
  - Shallow water ice detected within ten to hundreds of meters of the surface
- Surface albedo (MARCI) and surface thermal emission (MCS)



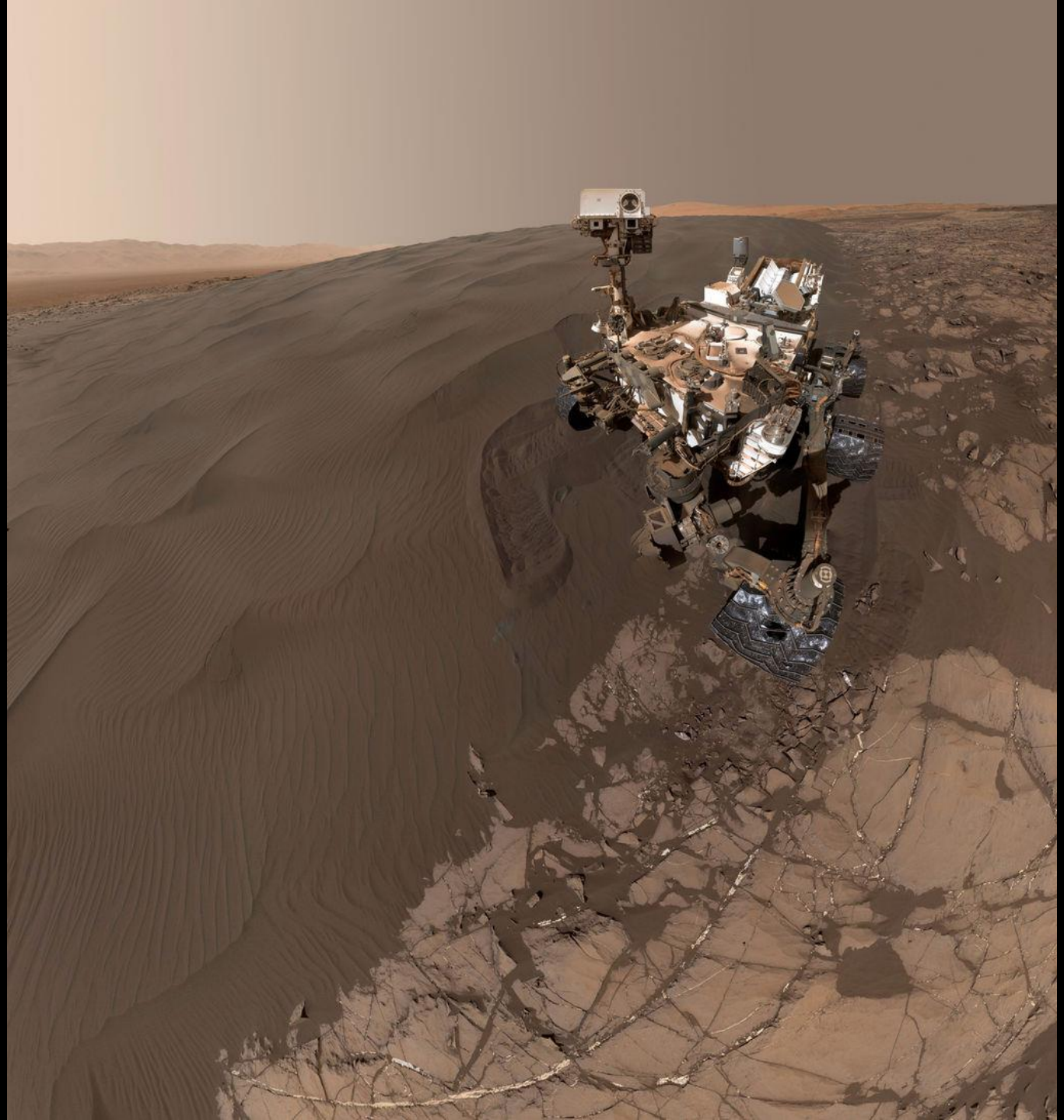
Seasonal Flows in the Central Mountains of Hale Crater

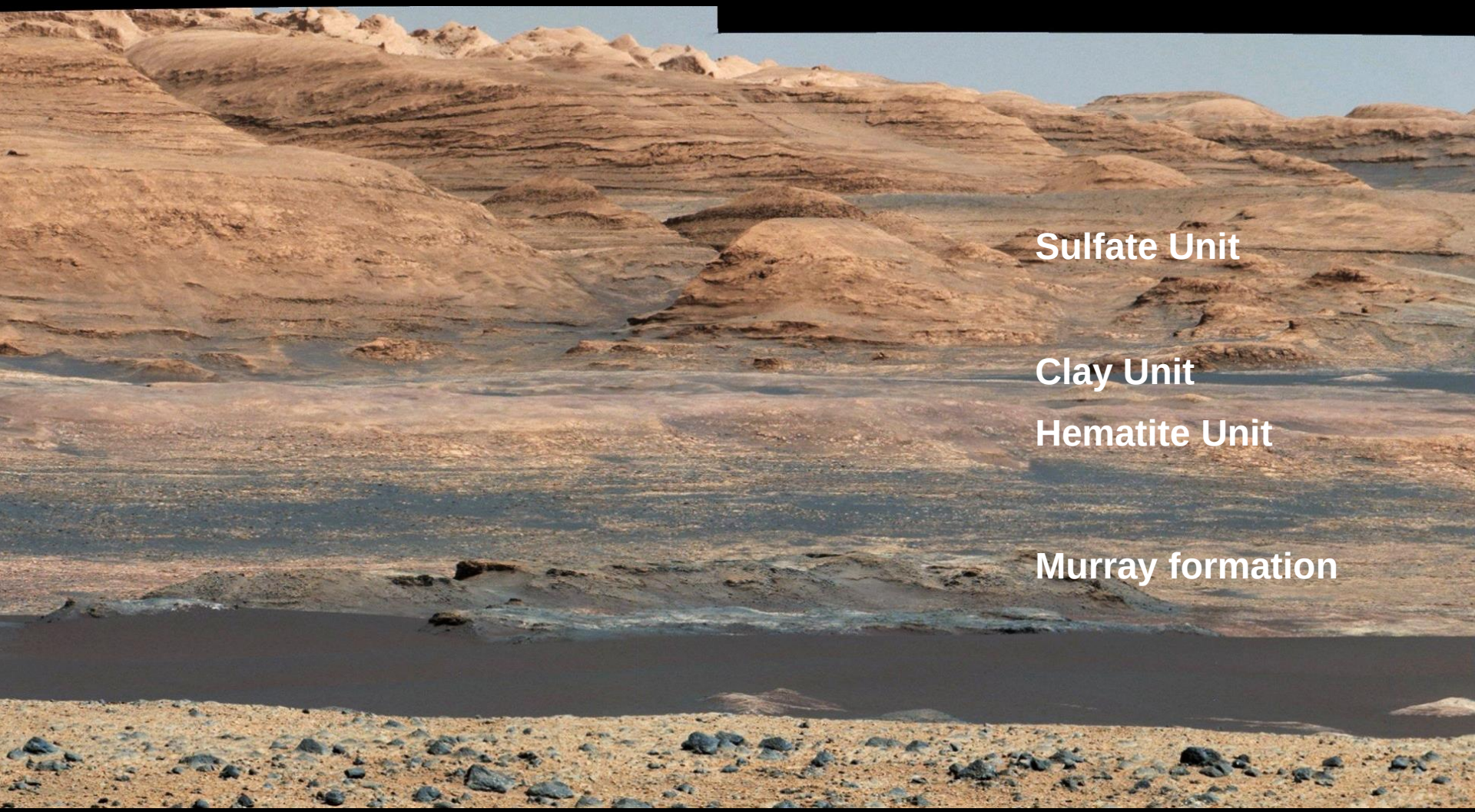
Recurring slope lineae (RSL) are active flows on warm Martian slopes that might be caused by seeping water. One of the most active sites known on Mars in in the central peaks (uplifted mountains of deep bedrock) of Hale Crater.

MRO-13

HIRISE

uahirise.org/ESP_040170_1440



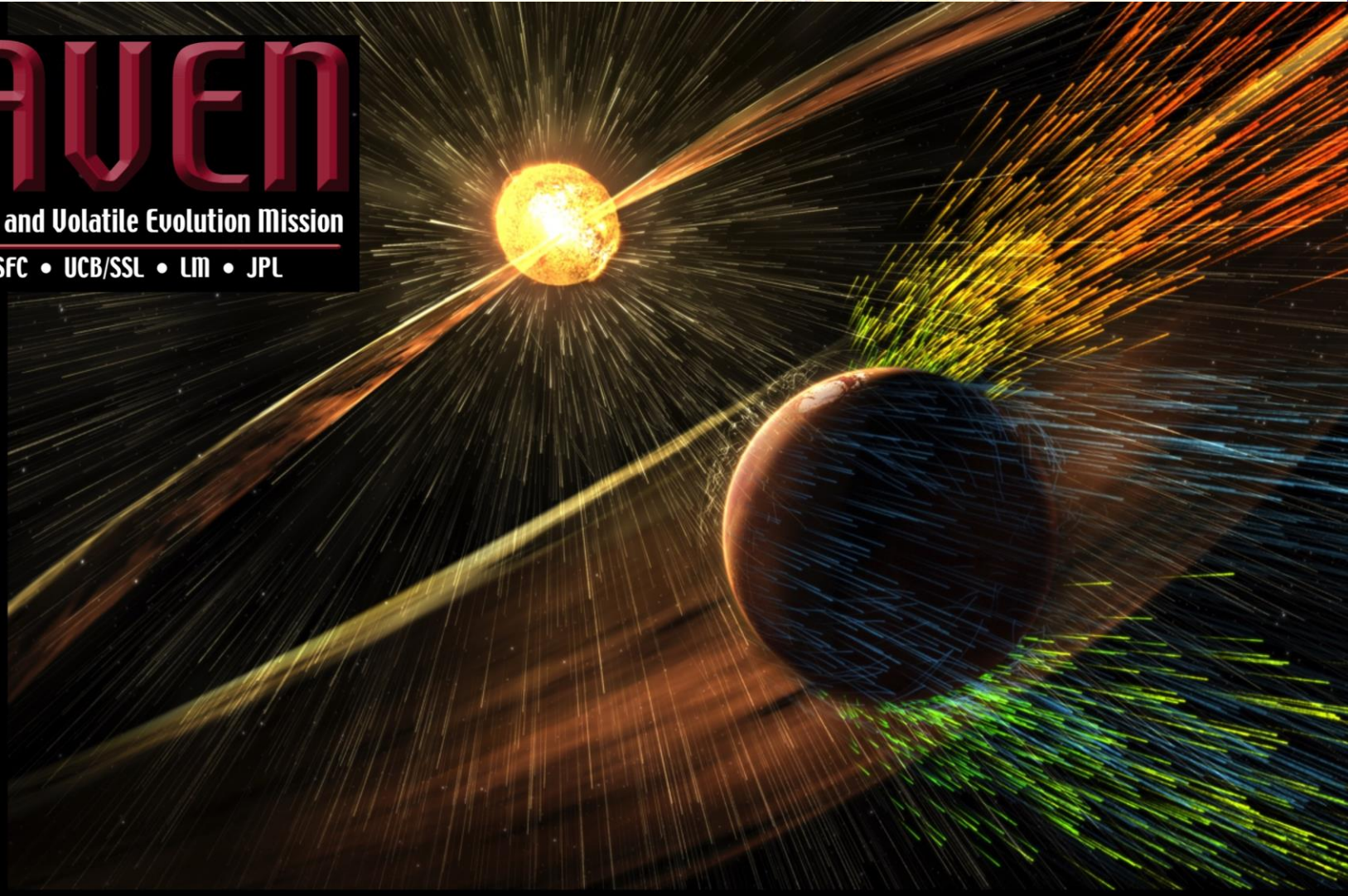


NASA/JPL-Caltech/MSSS

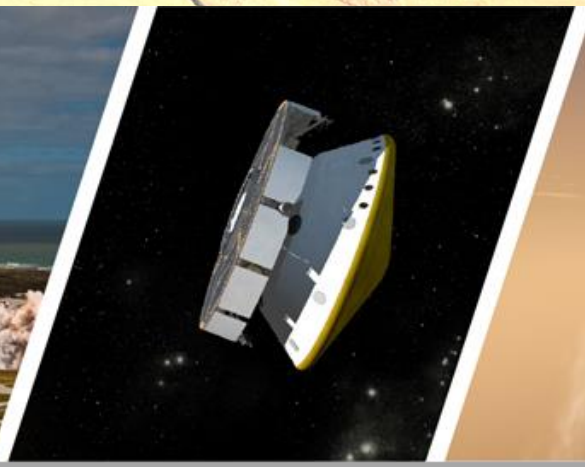
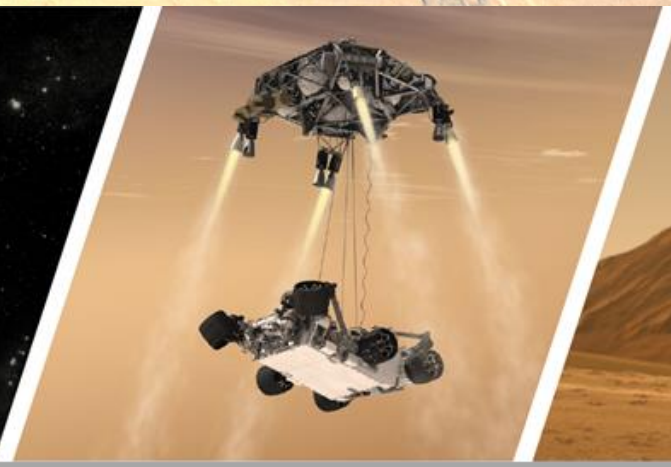
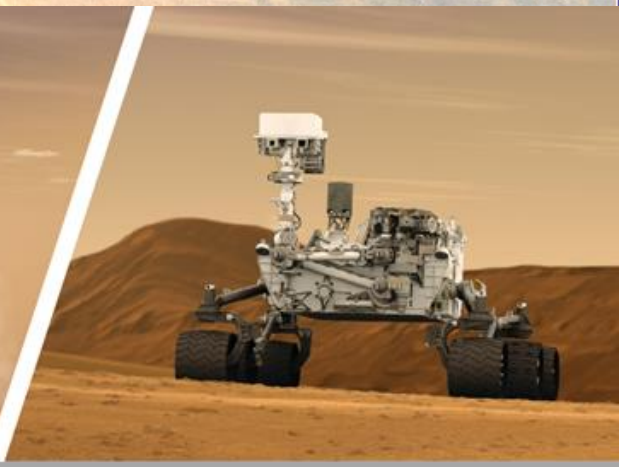
MAVEN

Mars Atmosphere and Volatile Evolution Mission

CU/LASP • GSFC • UCB/SSL • LM • JPL



M2020 Mission Overview

LAUNCH

- MSL Class/Capability LV
- Period: Jul/Aug 2020

CRUISE/APPROACH

- 7.5 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (Range Trigger and TRN baselined): guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation
- Curiosity-class Rover

SURFACE MISSION

- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1.5 Martian year liefetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

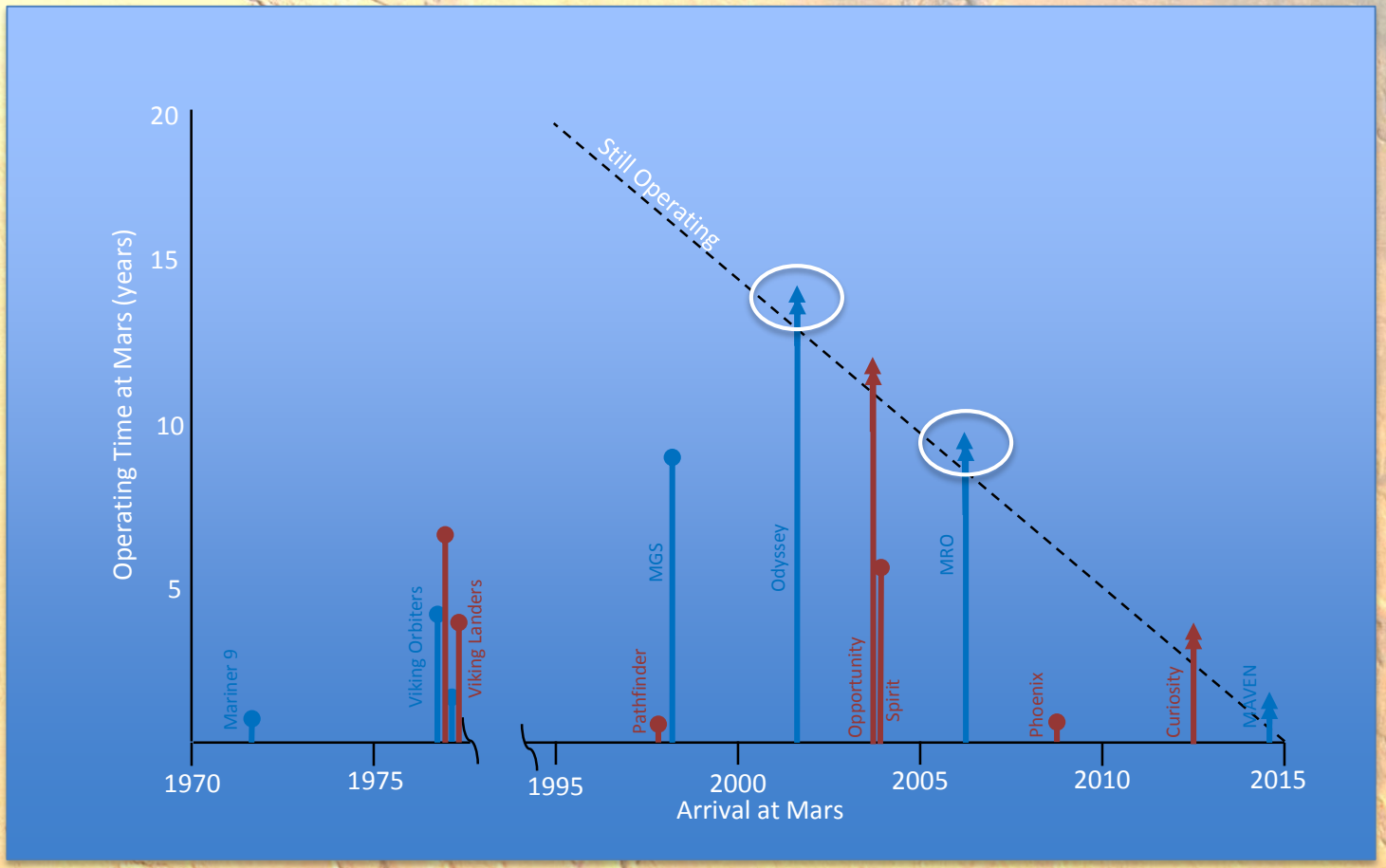
M2020 mission elements

M2020 Update

- Project Confirmation Review (KDP-C) held on April 27. Working through handful of actions requested by Associate Administrator.
- Terrain Relative Navigation (TRN) has been added to the baseline mission under a collaboration with STMD. Addition of TRN can augment surface productivity improvements by allowing access to landing sites with Regions of Interest in close proximity.
- Microphone capability has been baselined with the EDL cameras
- Surface operation productivity improvements have been identified, prioritized, and baselined
  - 1.5 Mars year hardware qualification
  - 5 hour tactical timeline
  - Faster traverse using TRN avionics for image processing and navigation
  - On-board autonomy for traverse planning and remote science productivity
- Helicopter technology demonstration is being considered for addition to the mission
  - Solar powered, with demonstration objective of 5 autonomous flights
  - Mars 2020 Project conducted accommodation study during Phase B
  - Technology development and testbed unit flights ongoing during FY16
  - Decision whether to add this tech demo to the baseline should be made by CDR.
- Project is proceeding with critical design of flight system and payload, along with continued procurements and builds of heritage elements in order to buy down risk.

Project continues to make excellent progress, with plenty of challenging work still ahead. On track for Fall/Winter Critical Design Reviews.

Operating At and Around Mars

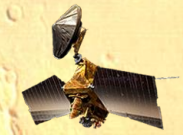


MEP has operated successfully and with longevity, but our infrastructure is aging, placing the decade of the 2020s at risk

Strategic View Forward

- US National Academies Planetary Science Decadal Survey (2012) gave the highest priority to “elements of the Mars Sample Return Campaign”
- The Mars 2020 mission and its payload begin this process with the characterization of a site and the careful selection and documentation of a suite of samples acquired and encapsulated for return
- The President’s NASA Budget Request for FY2017 provides $10M to begin early work on a future Mars orbiter missions beyond 2020 – with an emphasis on emplacing the infrastructure for the next decade

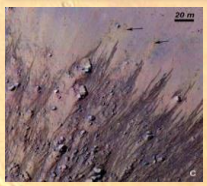
Next Orbiter Can Provide Capabilities that enable Many Future Pathways



Aging Orbiter Missions

Next Mars Orbiter

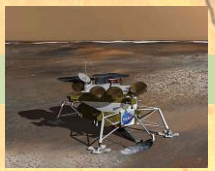
Infrastructure Continuity



Decadal Priorities

Resource Prospecting for future Landing Sites

The Future



On-going and future Surface Missions – need orbital support

NASA is studying various versions of the Next Orbiter

Desired Orbiter Capabilities

Renew and Update Aging Communications Infrastructure

- Essential to the future of Mars exploration; Laying the foundation for missions to come, while supporting ongoing missions in the early 2020's

Provide Continuity of High Resolution Imaging

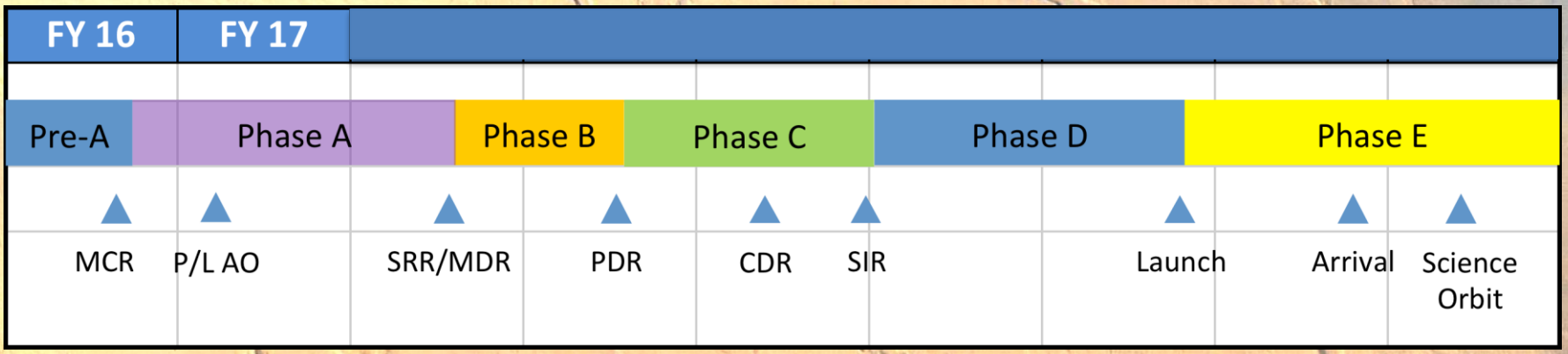
- Scientific Investigations for Landing Site Certification

Essential Orbital Support for Sample Return

Potential Resource Prospecting for
future Landing Sites and Exploration planning

Continuity of Relevant Remote Sensing

Notional Orbiter Project Lifecycle Planning Timeline

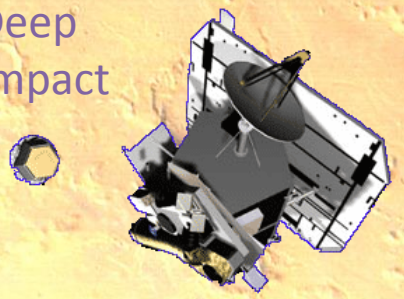


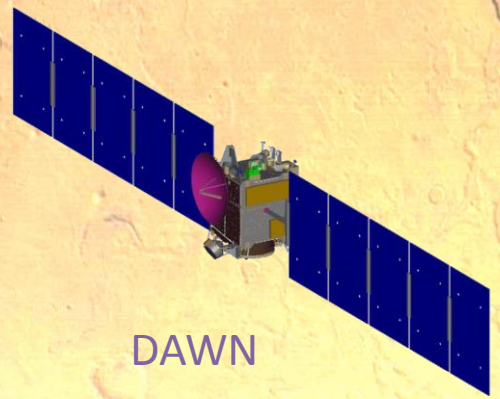
Phase A start in 2017 is essential, given that an orbiter arriving at Mars at the earliest opportunity would join Odyssey in its 22nd year of service and MRO in its 18th

Building from a Modest (Discovery-Class) Core Vehicle

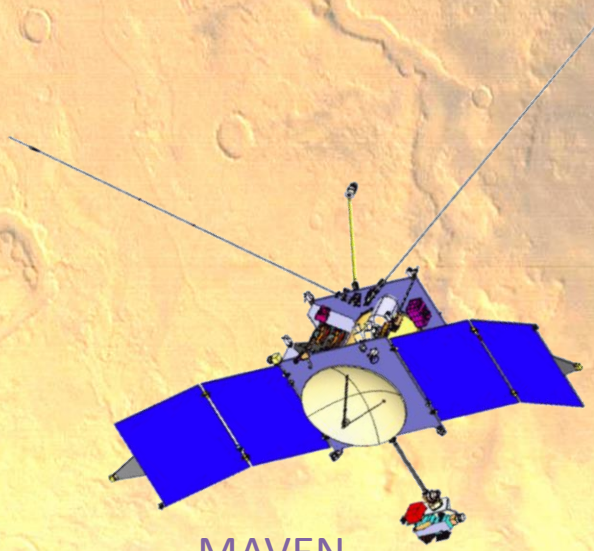
- Many basic spacecraft examples are architecturally flexible and adaptable to a wide range of missions
  - Provide Core Technical Functionality
    - Capable of Operating in Deep Space
    - Long Lifetime
    - Autonomous Operations
    - 3-axis pointing for imaging and communications
  - Adaptable to Solar Electric Propulsion, providing mission flexibility
    - Lowest cost launch vehicle
    - Increased mass delivery capability
    - Return to Earth capability

Deep Impact





DAWN



MAVEN

MEP Planetary Protection Related Activities

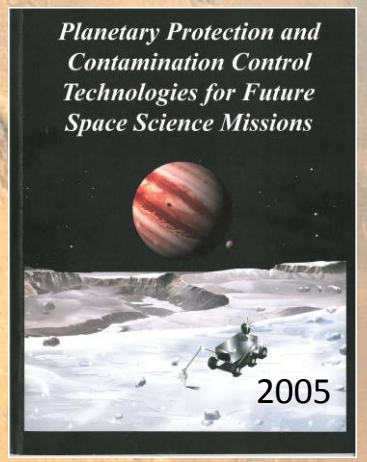
- MSL/Curiosity Operations Protocol
  - Instituted in January, 2016 to ensure Planetary Protection compliance
  - Part of MSL presentation
- Gale Crater Special Regions
  - Charter has been drafted to consider the likelihood and nature of special regions in Gale Crater
  - Characteristics, approach
- Planetary Protection Technology Definition Team
  - In PSD presentation

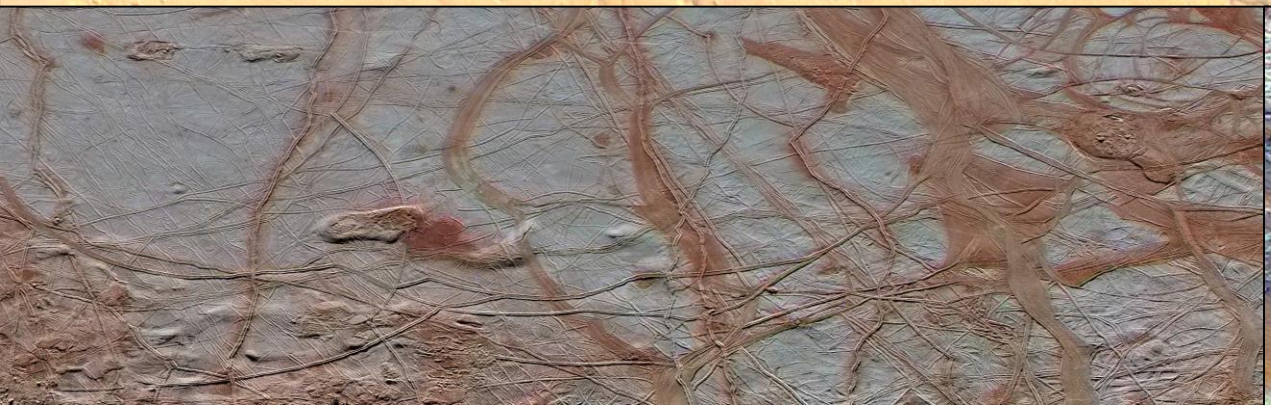
Gale Crater Special Regions

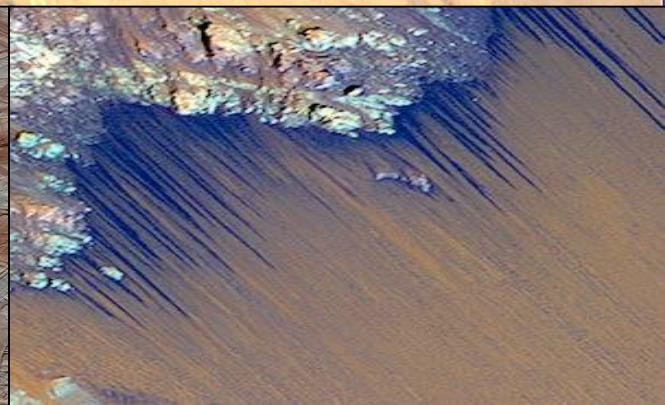
- MSL/Curiosity Project seeks scientific guidance on assessing the potential existence of natural and spacecraft-induced planetary protection Special Regions in Gale Crater
- Anticipated Tasks
  - Gather and review the recent observations and studies of interest
  - Determine the degree of confidence to which we can know whether or not Gale Crater has modern Special Regions
  - Recommend additional MRO and MSL/Curiosity measurements that can contribute to the identification or understanding of Special Regions
  - Recommend specific criteria that the MSL/Curiosity mission can use to identify and avoid potential Special Regions

Planetary Protection Technology Definition Team

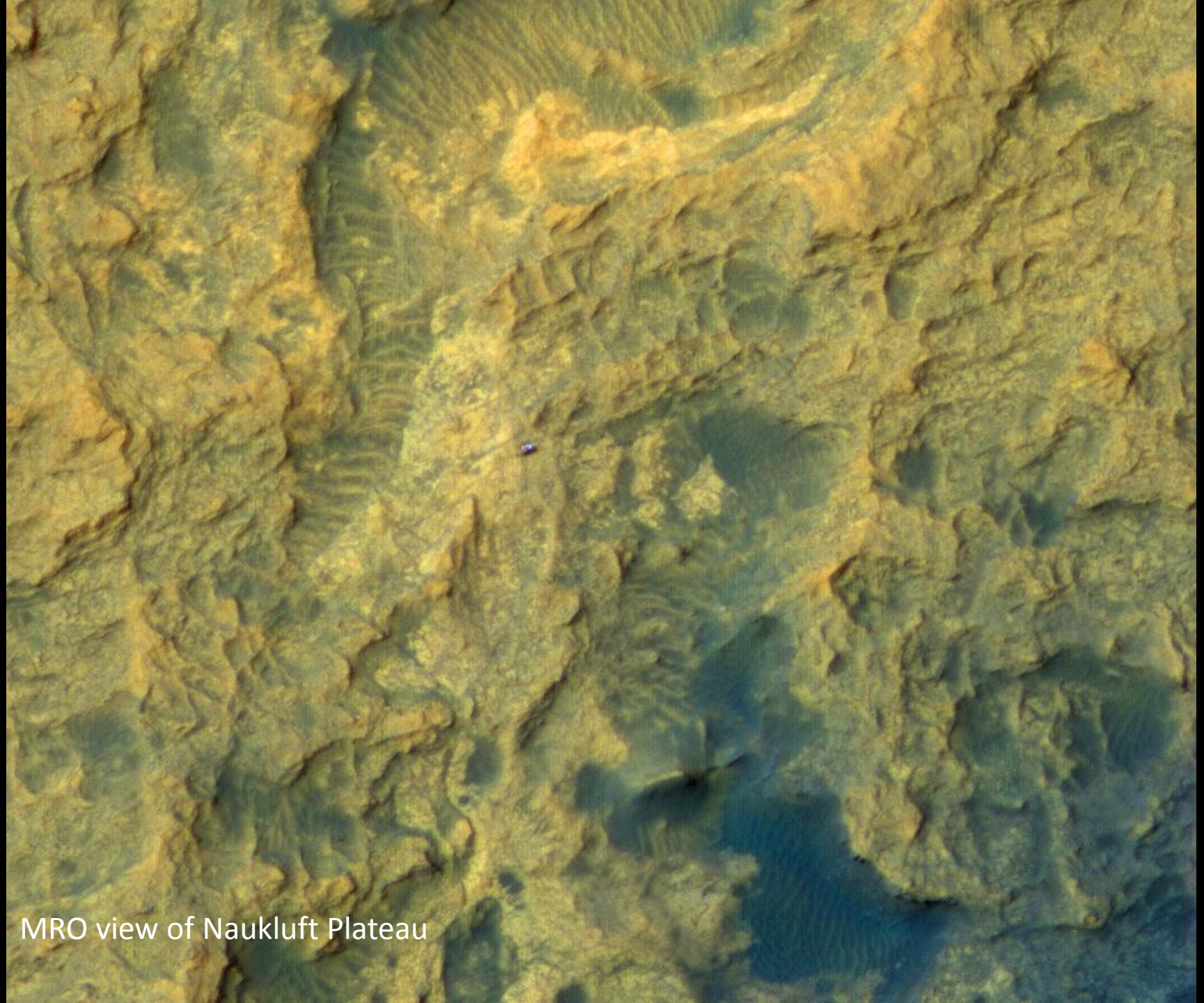
- Delineate planetary protection processes/techniques available or could be available to meet future planetary protection mission requirements
- Catalog materials & components compatible with planetary protection protocols
- Identify areas for technology development to verify processes or improve material compatibility
- Establish Team in late spring; report out by November
- ***Expected outcomes:***
  - ***Initial processes, techniques, and compatible materials list***
  - ***Identification of near-term research activities applicable to missions***
  - ***Provides Input for a Solicitation in ROSES 2017***







View from Naukluft Plateau



MRO view of Naukluft Plateau

Update from the Mars Science Laboratory/Curiosity

Ashwin Vasavada

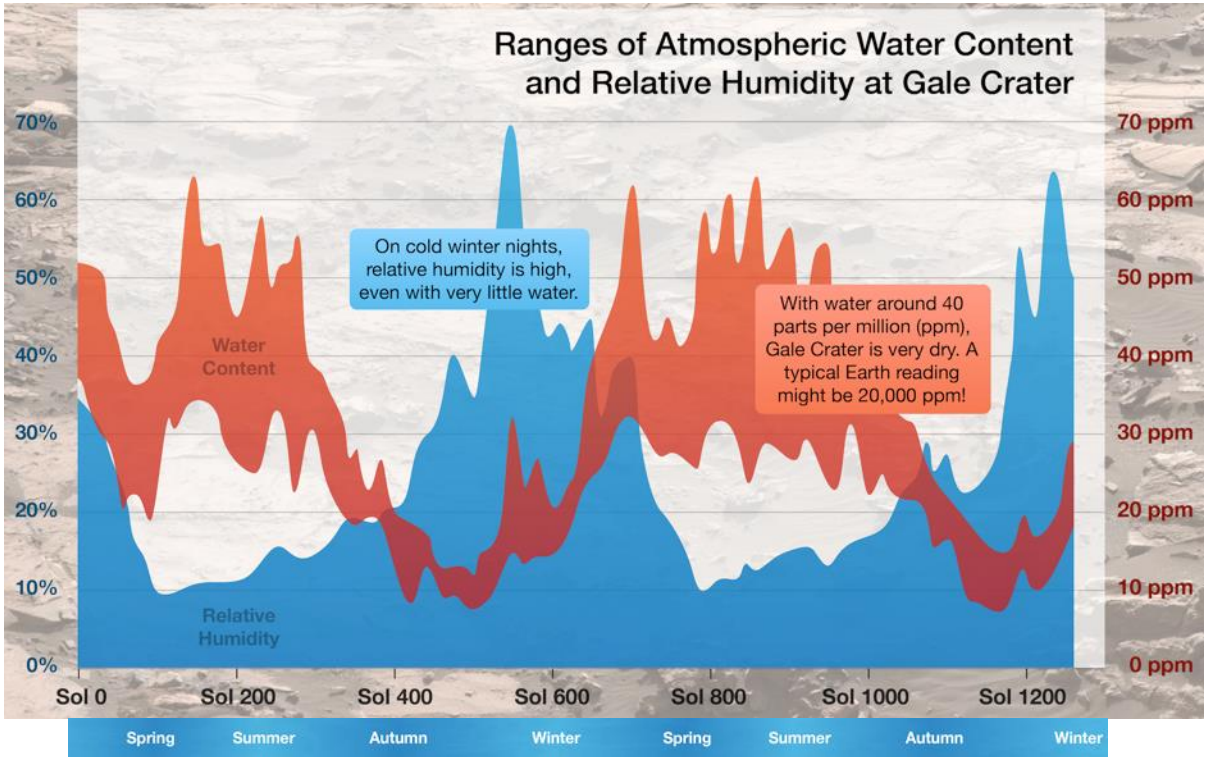
MSL Project Scientist

6/1/16

Outline

1. Two Mars Years of Meteorological Measurements
2. Update on Imaging of Potential Slope Activity on Aeolis Mons
3. Planetary Protection Compliance Protocol for Operations
4. Case Studies from Using the Protocol

Two Mars Years of Meteorology

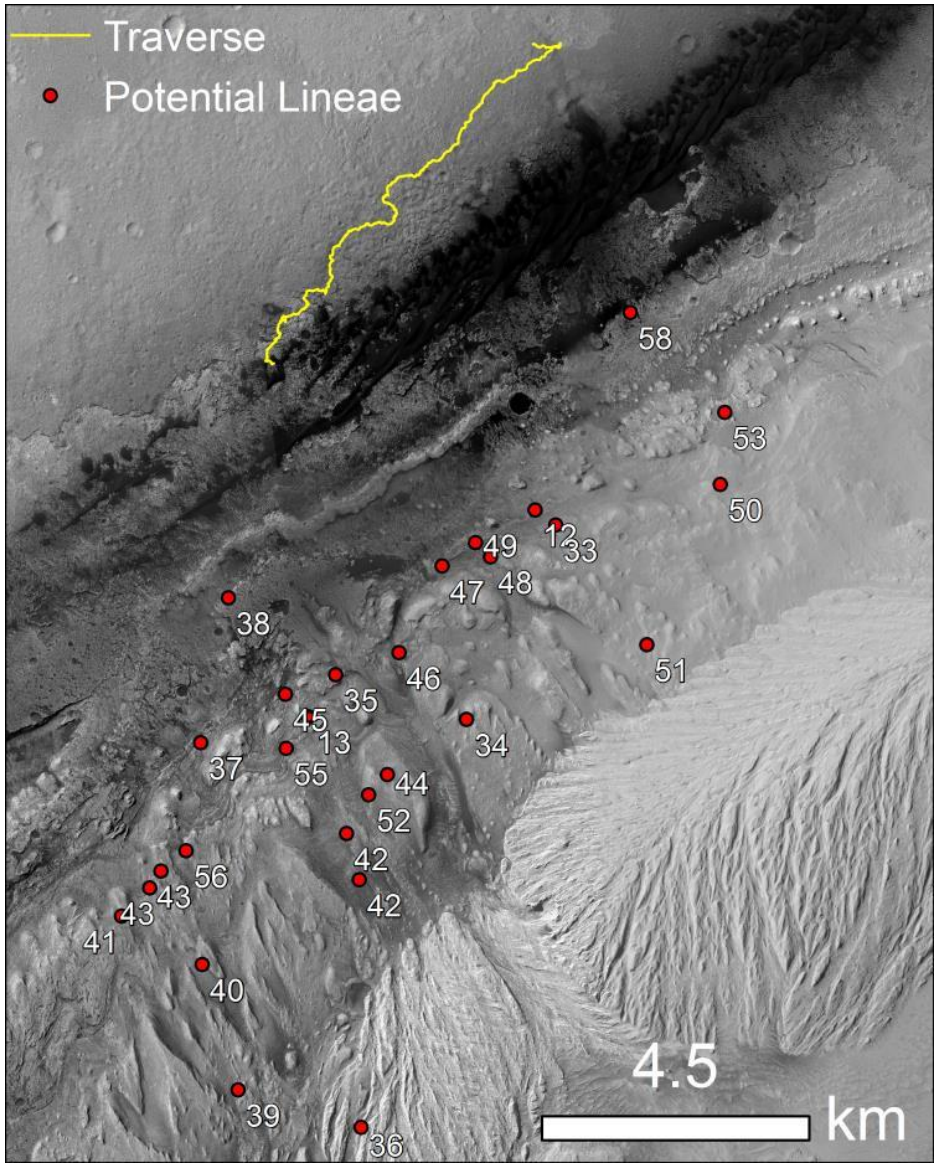


- Curiosity has measured relative humidity and absolute water vapor abundance for two Mars years. RH values reach ~70% at 1.6 m above the surface, potentially saturating near the ground where temperatures are colder.
- After measurements in both winters, no frost or seasonal hydration of the soil has been detected.

Update on Imaging Potential Slope Activity

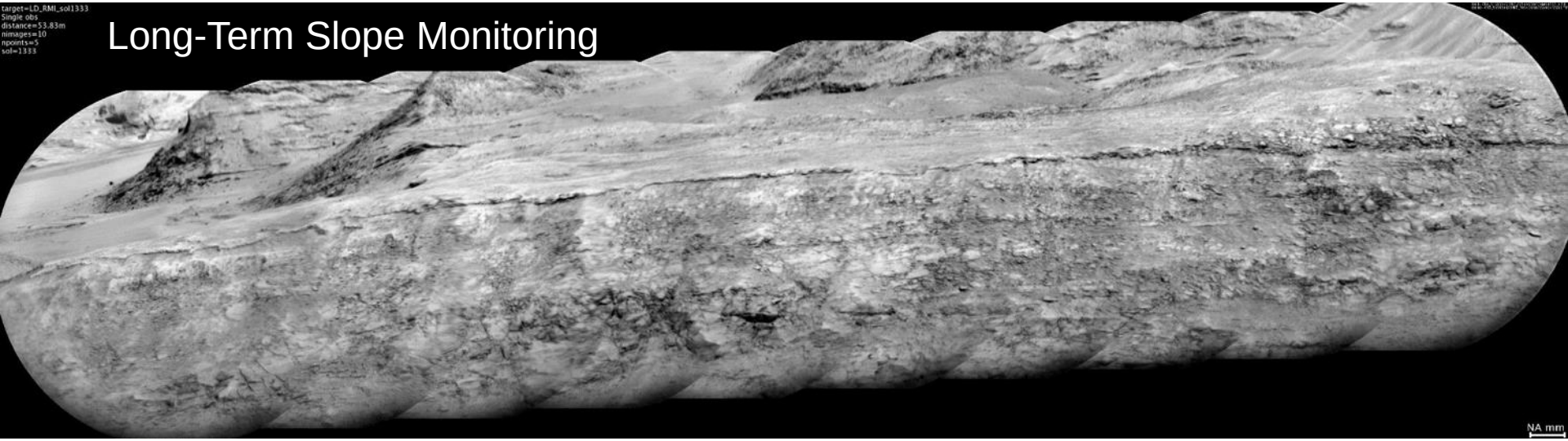
- ChemCam team member Ryan Anderson (USGS Flagstaff) has taken the lead on organizing potential slope activity on Aeolis Mons. ChemCam is the highest resolution imager on the rover.
- Ryan Anderson is collaborating with Colin Dundas of the MRO-HiRISE team to ensure that Curiosity images the slope lineae identified from orbit.
- So far, ChemCam has imaged seven HiRISE locations and an additional broad slope that will be visible for much of the remaining traverse.
- RSLs are confirmed by their multi-year behavior, not their appearance. Curiosity will continue to gather data and, in comparison with HiRISE, search for RSL-like evolution of these features.

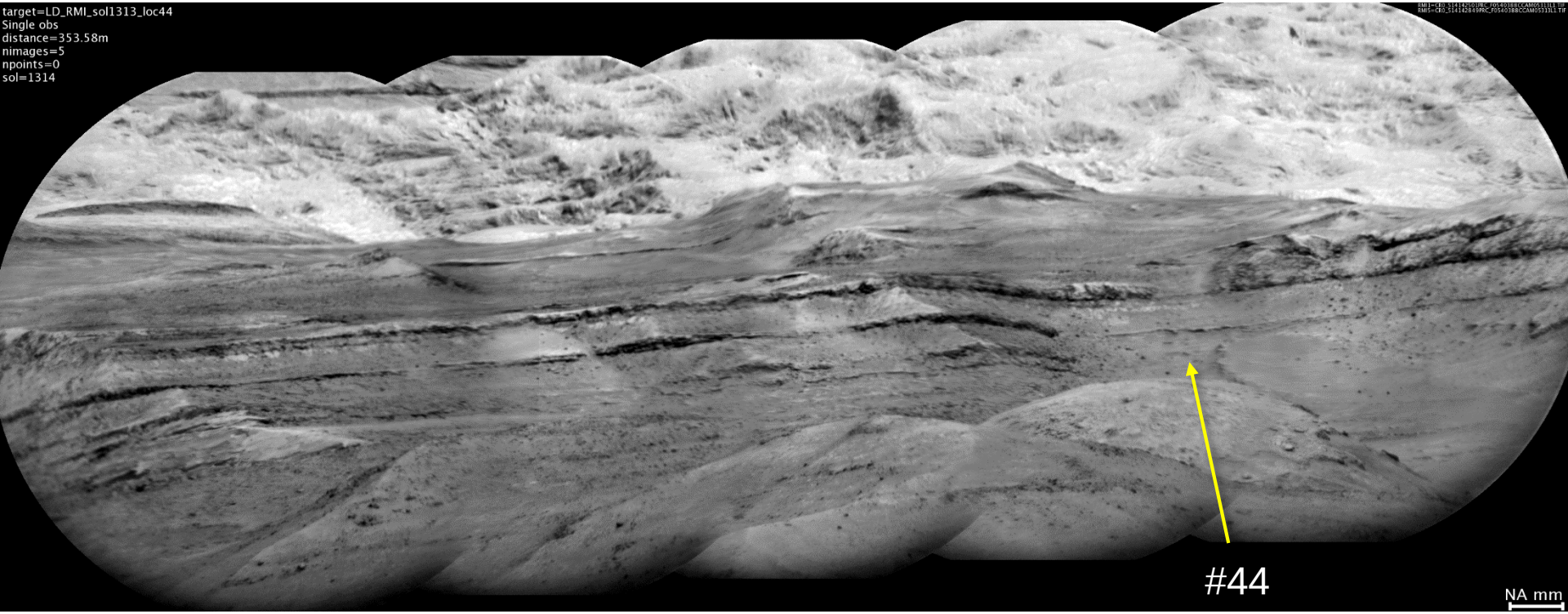
Update on Imaging Slope Lineae



- Numbered locations are dark lineae identified by HiRISE
- These were assessed in successive HiRISE images to look for RSL behavior. Two sites on northern Aeolis Mons (orange) show possible growth *at the limit of HiRISE resolution*.
- These two are candidate RSLs, pending additional observations.
- The rest do not indicate behavior consistent with RSLs, but may be active slope processes
- "Some of the observed slope features have characteristics similar to RSLs, but none is confirmed to be RSL and most have some characteristics suggesting other origins." (Dundas and McEwen, 2015)

Long-Term Slope Monitoring





MSL/Curiosity Operations Protocol

- In January 2016 the MSL/Curiosity Project began using a new protocol in daily rover operations to formally ensure that rover activities are compliant with the mission's Planetary Protection categorization.
- The protocol is intended to be responsive to the MSL PP Categorization, the criteria for Special Regions in NPR 8020.12D, and direction from John Grunsfeld received by MSL on 11/17/15.

MSL/Curiosity Operational Protocol

Protocol for Tactical Science Operations

- As the science and engineering teams are reviewing recently returned data and assessing mobility and arm activities, the SOWG Chair will inspect proposed contact science targets and drive paths for features that may represent potential Special Regions.
  - The SOWG Chair will use his or her expertise to identify any gullies, bright streaks associated with gullies, pasted-on terrains, dark streaks, possible geothermal sites, fresh craters with hydrothermal activity, modern outflow channels, or sites of recent seismic activity that have a significant probability of association with liquid water; and any potential Recurring Slope Lineae
  - The SOWG Chair should consult with the scientists on shift, particularly the Surface Properties Scientist, regarding any features of concern.
- If any potential Special Regions are identified:
  - Further arm and mobility activities will be precluded. Other rover activities may continue.
  - The SOWG Chair will notify the Project Scientist and Deputy.
  - The Project Scientist will convene a Special Regions Team (see following slide) to assess the feature of interest before arm and mobility operations may continue.
- If no such features are identified:
  - Operations proceed.
  - The SOWG Chair will note in his/her report (on MSL Reports) any features that were discussed as potential Special Regions and why they were judged not to represent potential Special Regions.
- At the Activity Plan Approval Meeting, when arm and mobility plans are finalized and visualized, the Tactical Uplink Lead will poll the SOWG Chair as to whether the plan is “cleared” or “not cleared” for planetary protection.

MSL/Curiosity Special Regions Team

- The MSL Special Regions Team will review features identified as potential Special Regions by the tactical team. Their objective is to provide a more thorough analysis than what can be accomplished on the tactical timeline, but with the goal of providing a rapid decision on whether operations may proceed. The Special Regions Team will review the observed features and any supplementary data that may be relevant to their determination. For example:
  - Other available context imagery or compositional measurements
  - Temperature and relative humidity measurements
- The Special Regions Team may request additional remote science from the tactical team to aid their determination. For example:
  - Additional imagery, spectroscopy, or LIBS measurements (if in range)
- The Special Regions Team will consist of:
  - The MSL Project Manager and Project Scientist
  - The MSL Program Scientist
  - The JPL Planetary Protection representative
  - TBD MSL science team members with expertise in geology, climatology, and astrobiology
- The decision whether to clear the rover for operations will be made by the MSL Project Manager based on the deliberations of this group.
- If the Special Regions Team upholds that the features may represent Special Regions, deliberations a summary of the data for the decision will be sent to the JPL MPO, HQ Mars Director, and the PPO, and further discussions between Project, Program, and PPO representatives will be organized to determine next steps (e.g., study, measurements, rover operations). If not, all MSL operations will be cleared to proceed and the information on the deliberations will be included in the weekly Mission Manager report.

MSL/Curiosity Operational Protocol

Science Team Awareness and Training

- All Science Operations Working Group (SOWG) Chairs (i.e., the lead scientist on any given day of MSL operations) have been trained by the Project Scientist on the criteria for Special Regions and the PP Categorization, and on the new operations protocol.
- The full MSL Science Team has been briefed by the Project Scientist on the criteria for Special Regions and instructed to report any relevant observations to the SOWG Chair or Project Scientist.

Case Studies

Use of the protocol began on Sol 1214 (January 4, 2016)

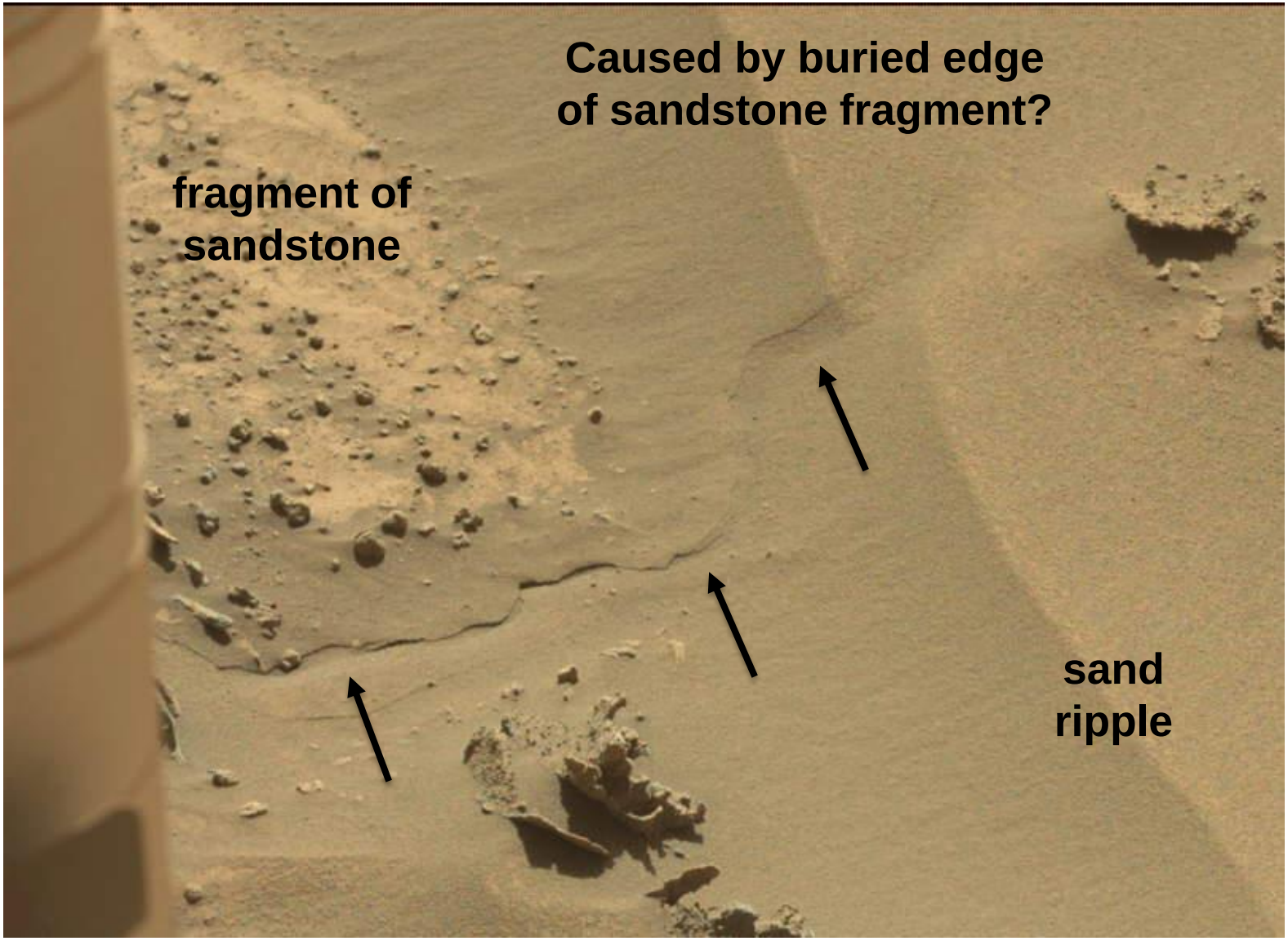
Discussion and documentation of features of interest during tactical planning:

- Sol 1259 – sandy slope with small avalanche
- Sol 1266 – differential erosion of thin sand layer gives appearance of channel
- Sol 1277 – buried edge of sandstone block gives appearance of channel
- Sol 1307 – sandy slope with small avalanches

All concerns were resolved early in the planning day; none halted operations or required convening a Special Regions Team.

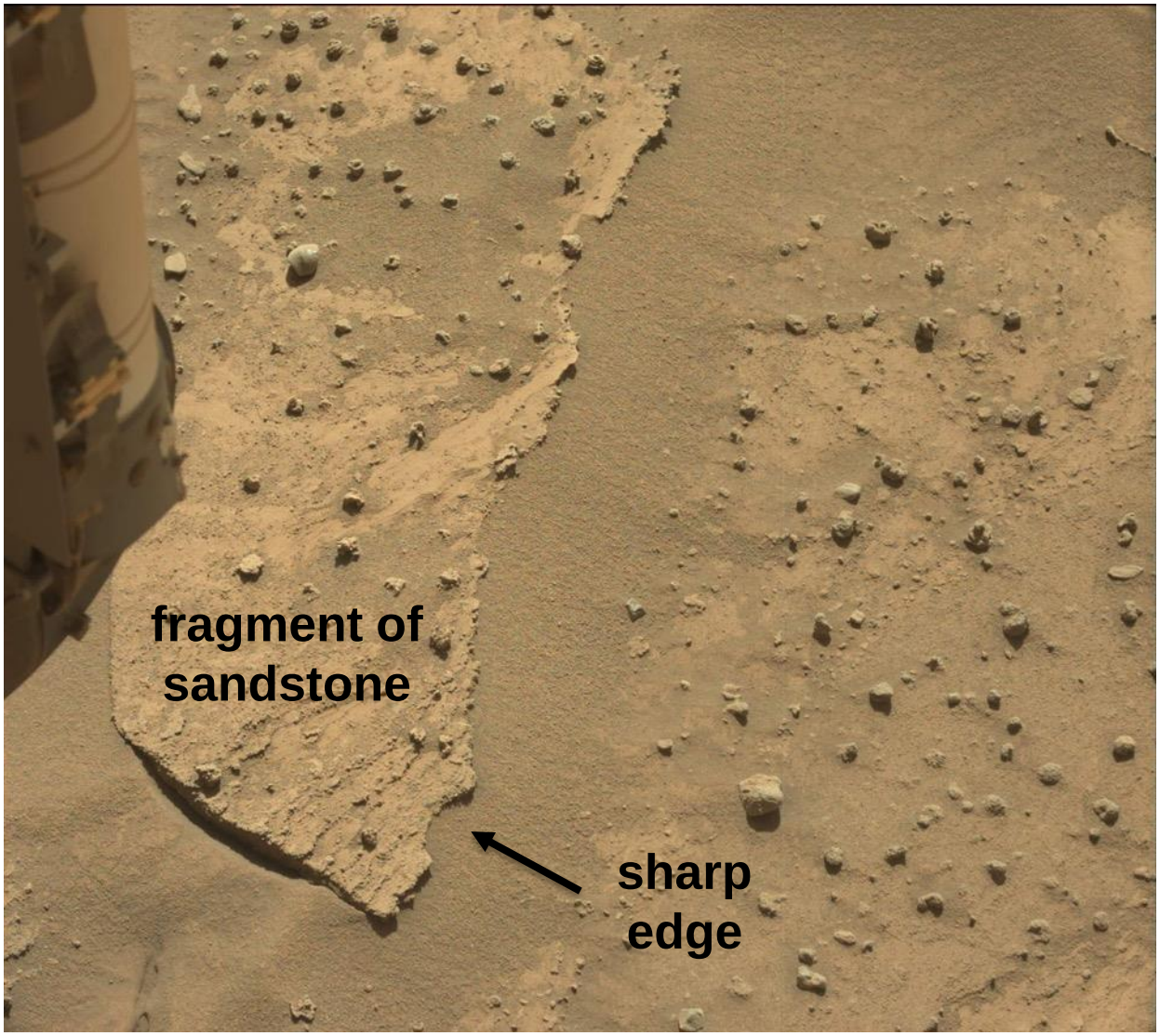
None was determined to indicate the action of liquid water.

Case Study – Sol 1276



Case Study – Sol 1276

Possible analog



Case Study – Sol 1307

Dark sand avalanches continue to be a common feature of the landscape. The science team continues to interpret these as dry avalanches on over-steepened, sandy slopes that are covered by brighter dust and slightly indurated.